Generation-environmental

Memorandum to the
Royal Commission on
Electric Power Planning
with respect to the
Public Information Hearings

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Section 2 Generation - Environmental List of Short Forms

API	Air Pollution Index
DRL's	Derived Release Limits
GS	Generating Station
HWP	Heavy Water Plant
ICRP	International Commission on Radiological Protection
IJC	International Joint Commission
ppm	Parts per million
Rem/y	Rem per year
^{o}C	Degrees Celcius
^{o}F	Degrees Fahrenheit

2.3 GENERATION ENVIRONMENTAL

2.3.1 Development of Environmental Studies and Environmental Assessment

Environmental studies are carried out for each of the three major phases involved in the introduction of a new Ontario Hydro generating facility to the existing system; i.e., site selection, site development, and during the pre-operational, commissioning and post-operational period. The term 'environment' is used in its broadest sense and encompasses the community, land use, aesthetic and social conditions in addition to physical and biological conditions.

During the site selection phase, each potential site is assessed as to the effects on the environment which might arise from future construction of generating facilities at the site. A comparison of these assessments contributes to ultimate site selection.

During the site development phase, more detailed study is undertaken of the site selected and an assessment is made of the possible influences brought about by construction and operation of a specified type and size of generating station.

During the construction, commissioning and operating phases of a generating station, continuing on-site monitoring is maintained to determine the actual influences of the project on environmental conditions.

The first formal environmental studies at Ontario Hydro generating stations commenced in 1967 and were confined to studies of effects at operating stations. In 1968, the first program was started at a station prior to operation in order to develop baseline data against which the subsequent operation of the station could be compared.

In 1971, following a request from the Ministry of the Environment, Ontario Hydro initiated a program of on-site studies at sites where approval to construct a generating station was to be sought. The results of on-site studies have been incorporated into documents supplied to the Ministry and used as a basis for evaluation of the project. Ontario Hydro published its first document, called an Environmental

Assessment, in 1972, before the Green Paper on Environmental Assessment had been issued.

Prior to 1971, sites had been acquired with no formal environmental assessment for the approval. In 1972, Ontario Hydro commenced a site selection process whereby public participation and environmental concerns contribute to the overall site selection process (1). This first site selection process, involved comparison of several sites which had been identified prior to environmental analysis. The present site selection procedures include consideration of environmental factors at the initiation of the whole process, that is, when a regional need for power has been determined by System Planning (7).

Environmental studies have therefore evolved over the last 8 years to include progressively earlier phases in the life cycle of a generating facility. The procedures of site selection and project approval will come under the provisions of the Environmental Assessment Act, 1975. All generating station projects after Atikokan will be evaluated under the Environmental Assessment Act. Environmental Assessments and Analysis have been previously prepared for the following projects (1,2,3,4,5,6,7).

Project	Environmental Assessment Issued
Wesleyville	April 1973
Pickering B	October 1973
Bruce B	February 1974
Bruce HWP, B, C, D	February 1974
Thunder Bay Extension	May 1974
Darlington	April 1975
Atikokan	April 1976

It appears that two documents, one at the end of each of the site selection and project approval stages, will be required to meet the provisions of the Act. Discussions are presently being held with the Ministry on the specific content of each of these documents. The first site selection process designed to conform to the provisions of the Act is now taking place in the North Channel of Lake Huron.

Because of the emphasis on thermal power generation during recent years, no approvals have been sought for hydraulic generating stations. When such projects are contemplated, Ontario Hydro will prepare Environmental Assessments on this form of generation in accordance with the Act.

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2. Generation Projects Division, Environmental Assessment, Proposed Generating Station for Pickering, October 1973.

3. Generation Projects Division, Environmental Assessment, Preliminary Proposal for Bruce Heavy Water Plants B, C & D, February 1974.

4. Generation Projects Division Environmental Assessment, Preliminary Proposal for Bruce Generating Station B.

5. Generation Projects Division, Environmental Assessment Proposed Generating Station for Thunder Bay, May 1974.

6. Generation Projects Division, Environmental Assessment, Proposed Generating Station for Darlington, April 1975.

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Line Number

2.3.2 Radioactive Emissions from Nuclear Generating Stations

2.3.2.1 Radioactive Emissions

(a) Maximum Permissible Releases

The maximum permissible releases of radioactive material from nuclear generating stations are based on maximum permissible doses for members of the public recommended by the International Commission on Radiological Protection (ICRP)(1). These are legisated in Canada by the Atomic Energy Control Regulations which are administered by the Atomic Energy Control Board (AECB). The ICRP is an independent, non-governmental body consisting of internationally recognized experts from many countries and a wide variety of scientific disciplines. Its recommendations have been accepted by the World Health Organization and the International Labour Organization, and are used as the basis of standards prepared by the International Atomic Energy Agency.

These standards have been developed over several decades and are based on numerous studies of somatic and genetic effects of high radiation doses and dose rates. The very stringent public dose standards adopted in Canada, and generally worldwide, are conservatively based on a linear extrapolation of dose/effect relations observed at high doses to zero dose, i.e., it is assumed that there is no threshold below which there ceases to be an effect. In Canada there are public dose standards for individual numbers of the public as well as overall population dose limits for the public living in the vicinity of nuclear power stations (Section 2.3.2.2). In general the "individual" dose standards are limiting.

(b) Ontario Hydro Design and Operating Targets

Ontario Hydro (2), in line with the ICRP recommendation to keep doses "as low as is reasonably achievable, economic and social considerations being taken into account" (3), has adopted a design and operating target for annual radioactive releases during normal operation, of 1% or less of those releases (DRL's) corresponding to the "individual" public dose standard. The maximum calculated dose to a member of the public living at the site boundary, resulting from releases at this "target" level, is within the normal variation of natural background

radiation, and is indistinguishable from it. This target is being met at Ontario Hydro's large multiunit power station where releases are usually substantially less than the 1% targets (4)(5).

The calculation of release limits from dose standards involves a knowledge of meteorology, of environmental pathways and biological concentration factors as well as a number of conservative assumptions regarding the living patterns and behaviour of the limiting group of the general population, which could lead to their receiving a larger radiation dose than average from the effluents of a nuclear generating station (6)(7).

(c) Monitoring

Station ventilation air which may contain significant quantities of radioactivity is released to the environment only at monitored ventilation discharge points. Controlled liquid releases occur via the condenser cooling water (CCW) discharge.

As a further check on the acceptability of the emission standards, on-going environmental monitoring programs are carried out in the vicinity of nuclear generating stations independently by Ontario Hydro and government agencies. These programs include the sampling of air, water and precipitation, as well as fish and locally produced milk. This serves as a check on the suitability of release limits, and any divergence from expected activity pathways would be detected long before any significant risk to man was posed.

It is recognized by the nuclear industry and the various national regulatory authorities throughout the world that certain long lived radionuclides which may be released during routine operation of nuclear generating stations may require limitation on the basis of dose commitment to the world population (8). Current world-wide monitoring shows that there is no concern on this account but additional limitations on the release of these radionuclides would be imposed if a significant increase in the radiation dose to the world population might ultimately result.

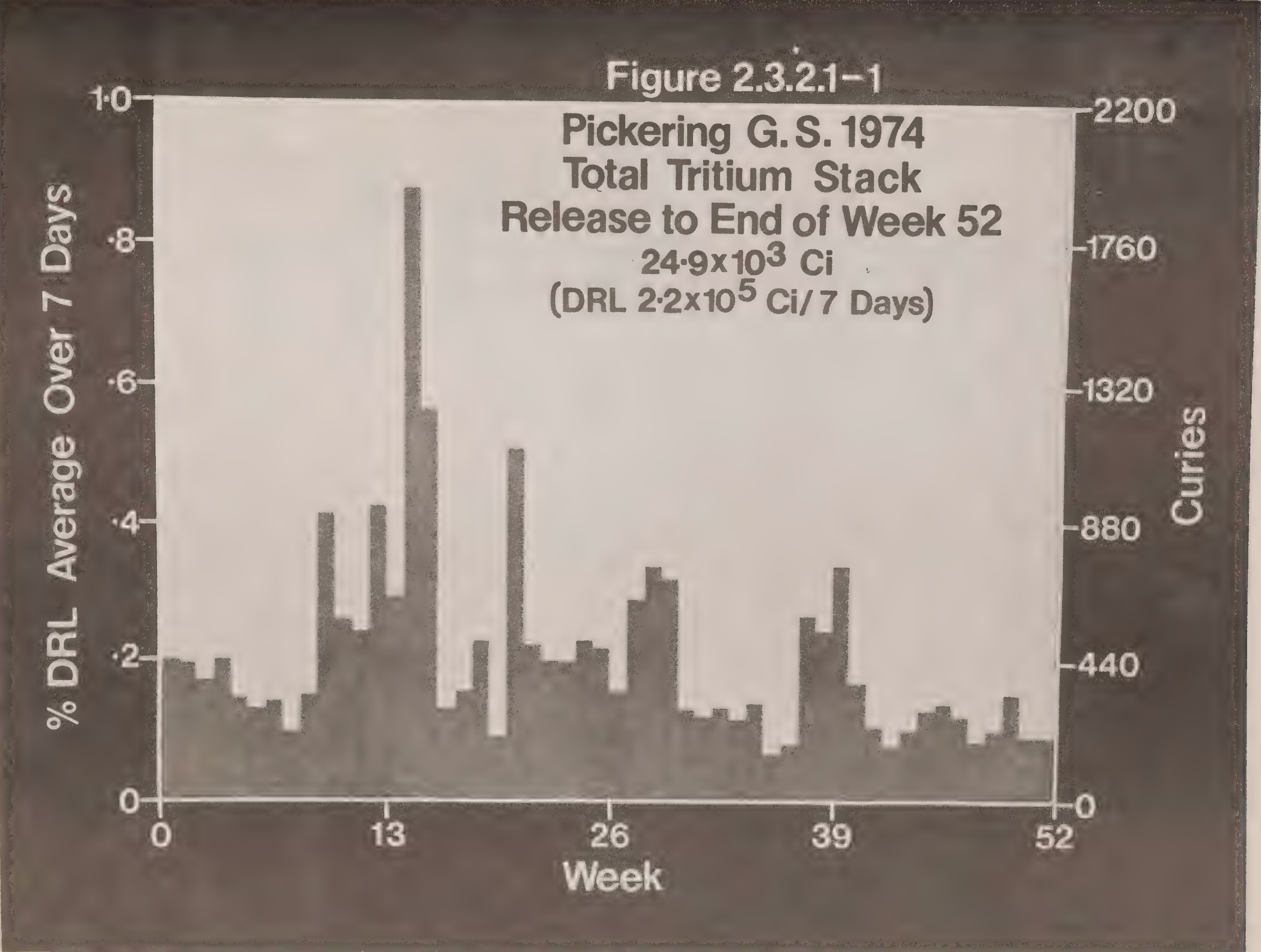


Figure 2.3.2.1–1

Figure 2.3.2.1–2

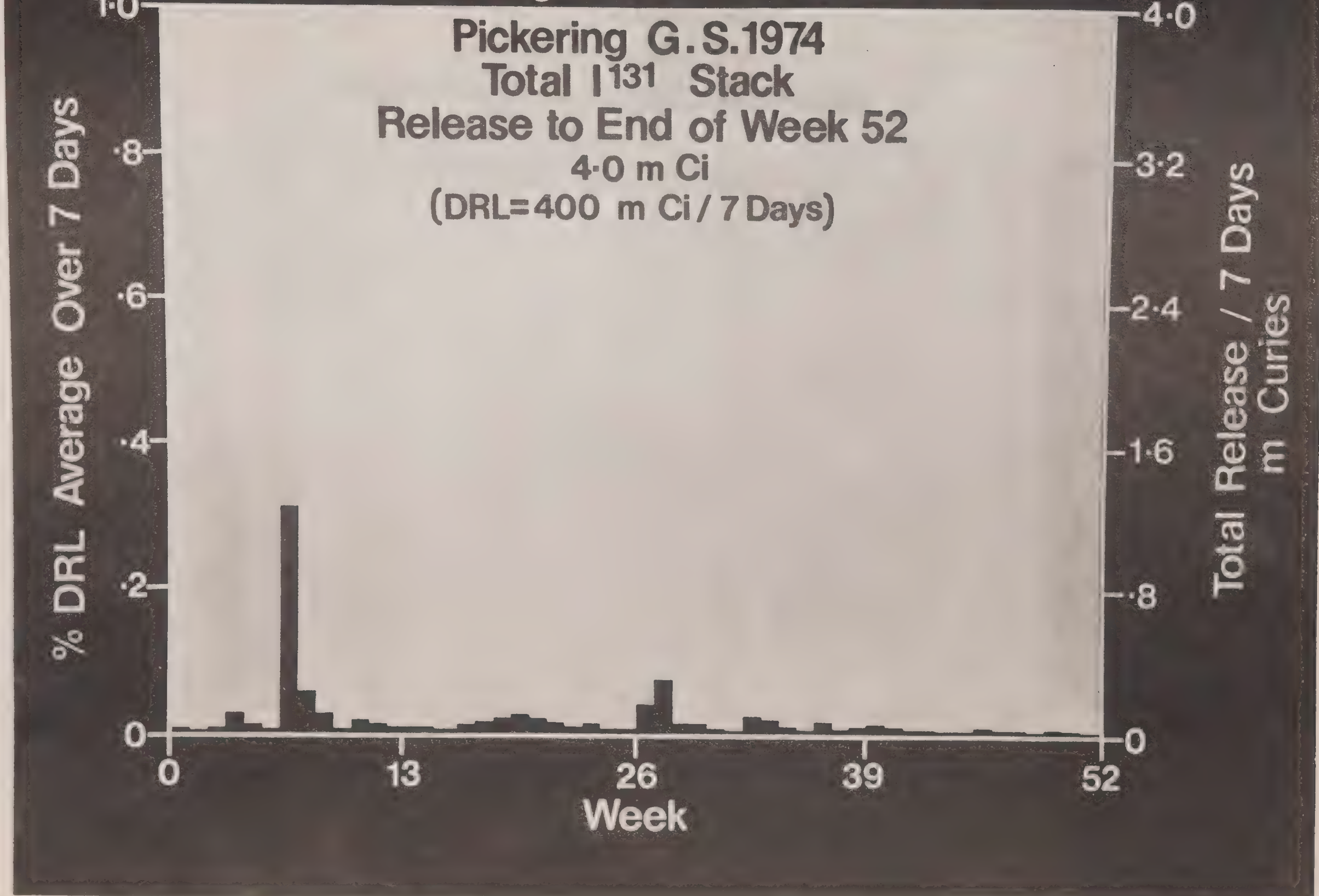
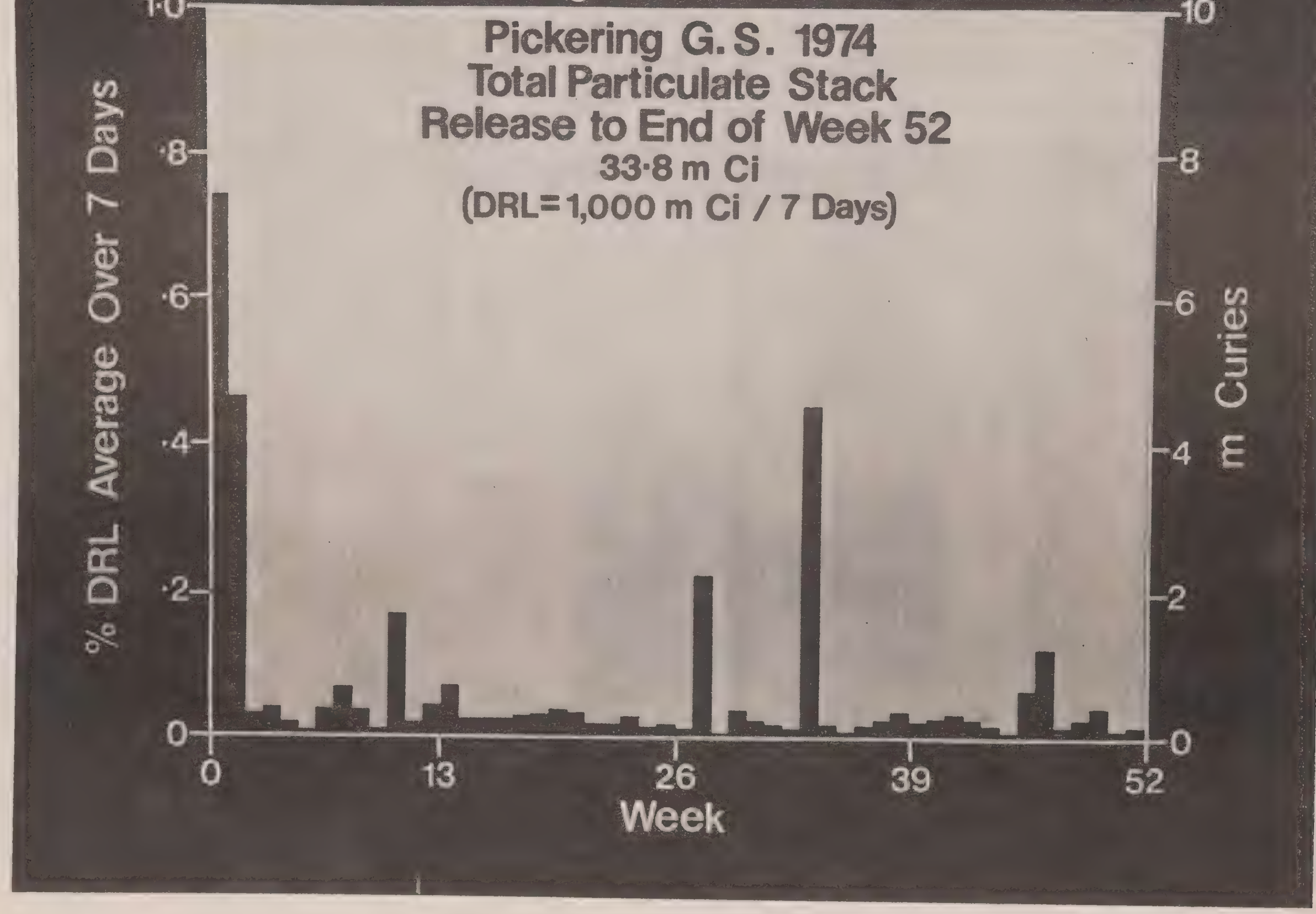


Figure 2.3.2.1–3



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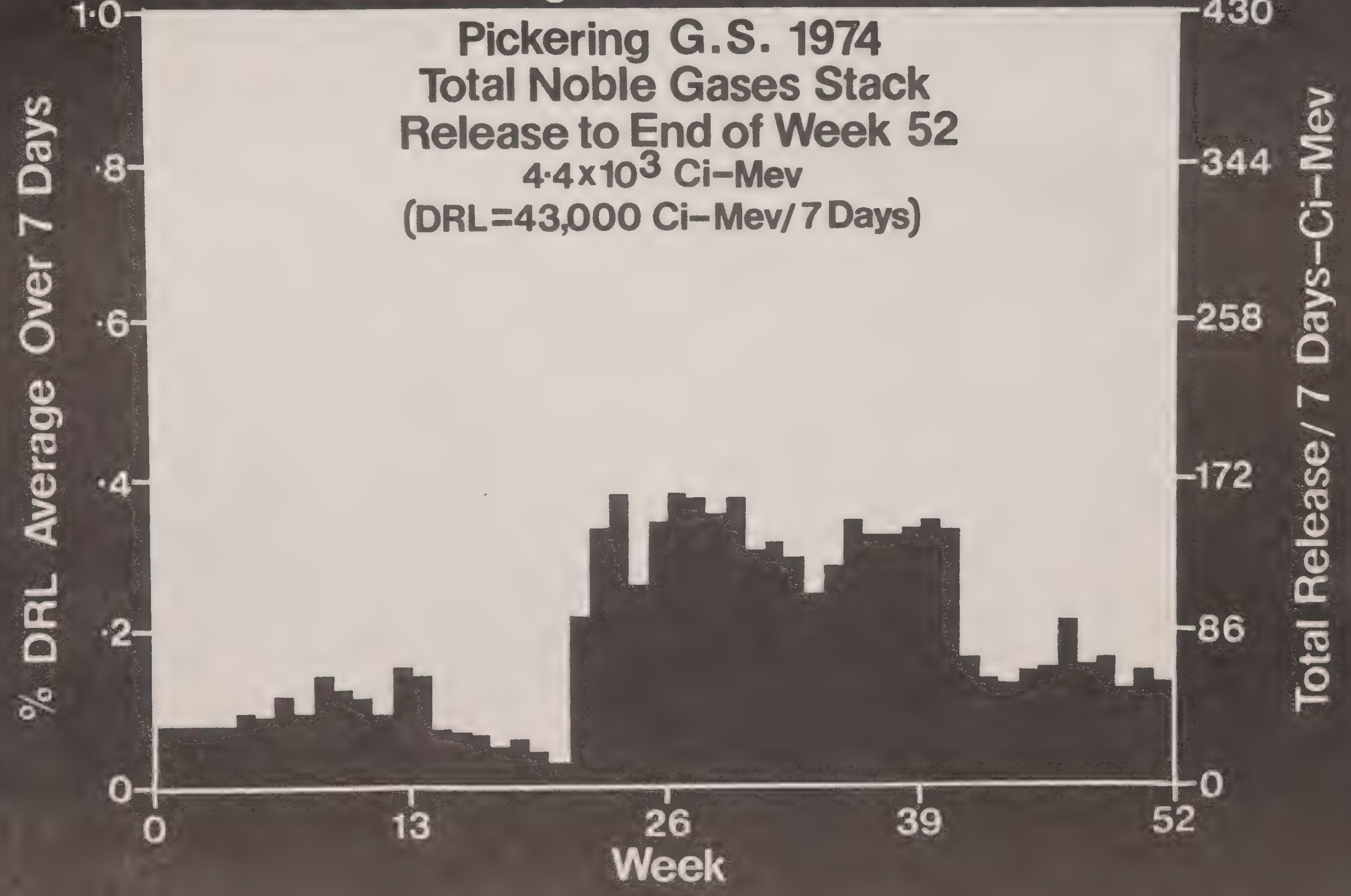

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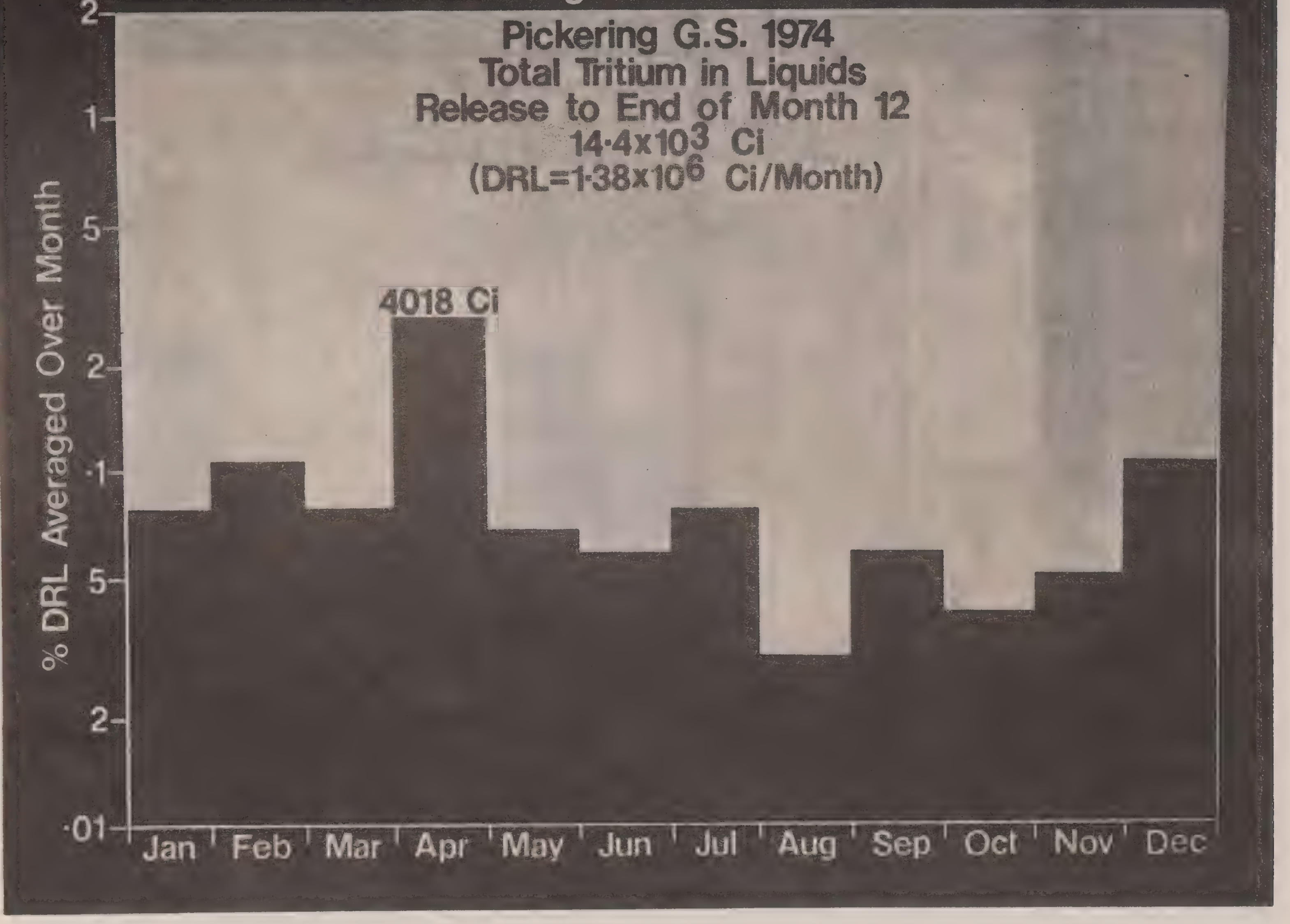

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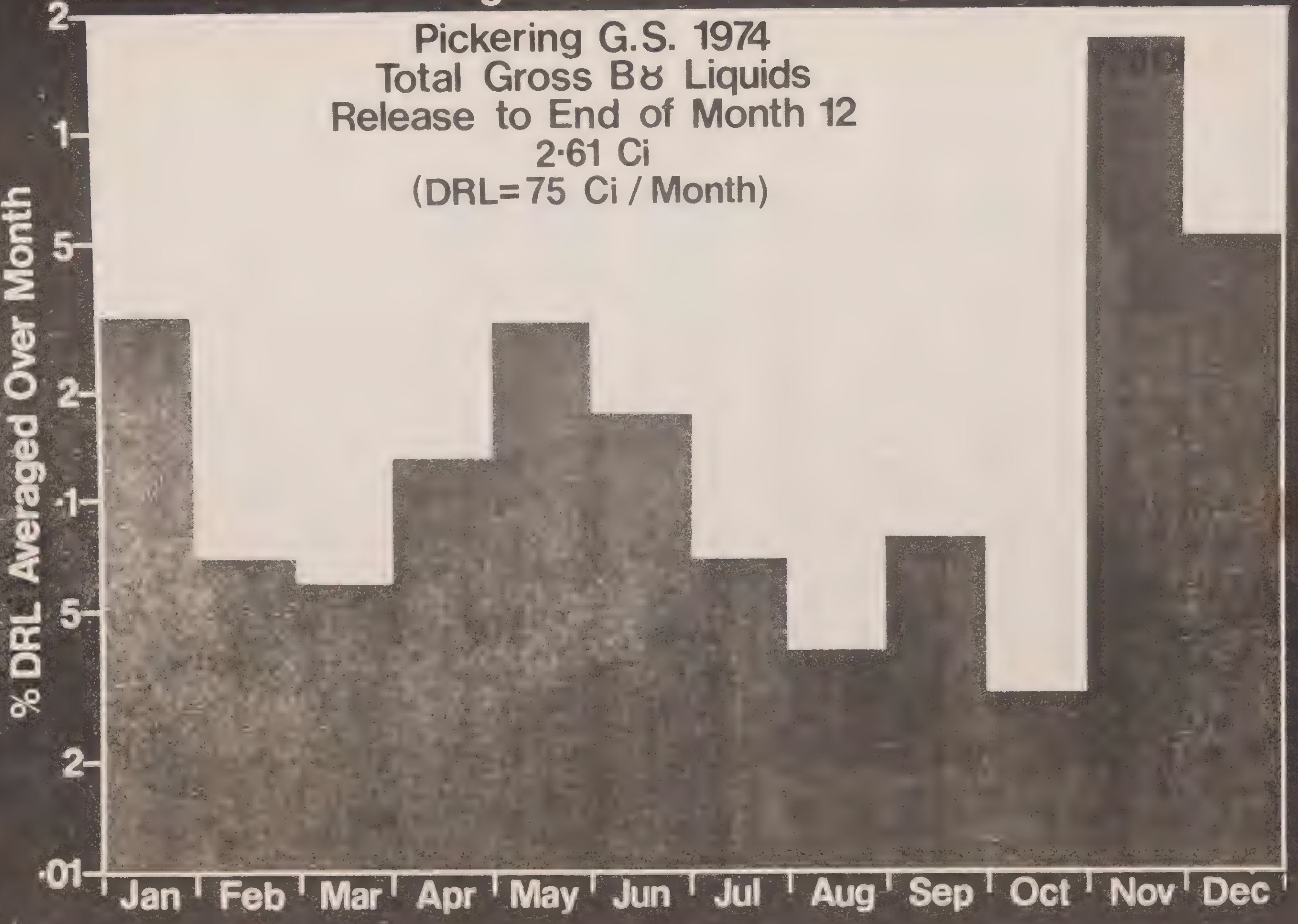

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2.3.2.2 Biological Effects of Ionizing Radiation

(a) Introduction

Based on human and animal data accumulated over the past 75 years, ionizing radiation is known to be able to cause both immediate and delayed effects: large, acute doses give rise to both immediate and delayed effects, while low-level chronic exposure is conservatively assumed to result in effects that could be delayed for a few decades.

Two types of biological effects may occur: somatic effects, that involve the person irradiated and occur during his or her lifetime; and genetic effects, that may occur in the descendants of the irradiated person. This pattern is true for all forms of ionizing radiation, whether it arises from radioactive material outside or inside the body.

In the context of the nuclear power program, and resulting exposure of occupational workers or the public, we are primarily concerned with chronic, low-level exposure. However, most biological effects have been observed only at doses and dose rates greatly in excess of these levels. Hence, the nature of the dose-effect relationship is critical in extrapolating from the observed data to the presumed effects of low doses within the maximum permissible dose limits and at environmental levels. For many years, these limits have been established on the conservative basis of an assumed linear relationship between dose and effect, i.e. it is assumed that the biological effects at low doses are proportional to those observed at high doses, that there is no threshold or minimum dose required for any effect, that chronic exposures are equally as effective as acute exposures, that the biological effects of radiation exposure are totally cumulative, and that there is no repair of radiation damage. This approach, which is likely to be conservative, permits an upper bound or limit of the effect to be estimated. The actual effect, if any, at low doses is likely to be between this assumed effect and zero. It seems unlikely that the actual occurrence of effects, or their absence, at the low doses relevant to nuclear power will ever be demonstrable because of their extremely low expected frequency, even on the basis of the upper bound, conservative estimates. These estimated maximum effects are quite small compared with the existing large natural frequency of such effects in the human population. The biological

effects of ionizing radiation are not uniquely caused by ionizing radiation. Rather, it may increase the incidence of diseases already present in the population as a result of many agents, e.g. chemicals, viruses, natural background radiation, etc.

(b) Somatic Effects

The important delayed somatic effects are cancer and leukemia. The bulk of the data evidencing a cause-effect relationship lie above a dose of about 30 rem and come from human population groups; the survivors of the bombings of Hiroshima and Nagasaki (0 to several hundred rem)(2), patients treated by radiation to alleviate crippling arthritic conditions of the spine (about 900 rem to spinal areas) (3), and early medical radiologists (4). The most pronounced evidence for somatic effects is for exposures exceeding 100 rem. By comparison, the estimated average annual dose to a member of the general population in Canada from nuclear power is currently 0.000003 rem(6). The conservatively calculated maximum annual dose on the Pickering station boundary is about 0.003 rem.

The health of the Japanese bomb survivors has been under detailed study for thirty years. The incidence of leukemia began to rise some years after exposure, but is now falling back. In those survivors who received doses over about 50 rem, some other forms of cancer are more frequent than in the survivors who received much smaller doses. These other cancers appeared after a longer delay than for leukemia. In the whole study period covering about 80,000 survivors, about 3,000 cancers have been observed. Based on unexposed control groups, approximately 2,850 would have been expected normally, i.e. only about 150 can be ascribed as additional effects due to high level radiation exposure.

In the spinal arthritic group of 14,554 adults which has been followed for up to 20 years since treatment, the chance of death from leukemia appears to have been increased by about 9-fold, from about 1 in 1000, the normal risk in the elapsed time period, to just under 1 in 100.

Data in the United Kingdom and the United States concerning pelvic irradiation of pregnant women(7,8), have been investigated for many years as a possible cause of an increased incidence of childhood cancer

in the first ten years of life following doses as low as 1 to 2 rem. It is now thought that this may be due to other factors, e.g. virus diseases during pregnancy, which led up to the pelvic examinations. Less cancer has been observed in the Japanese children irradiated in utero than would be predicted on the basis of the X-ray studies.

Below 30 to 100 rems and down to background levels (0.15 rem/y), many studies have been conducted in attempts to detect carcinogenic and other effects. These include studies of occupational exposures of radiologists and technicians (rems/y)(9,10), occupational exposures of atomic energy employees (a few rems/y)(11,12), populations exposed to high natural backgrounds (0.500 to 2.0 rem/y)(13), and natural background exposure of a large portion of the population of the United States (0.075 - 0.250 rem/y)(1,14). These epidemiological studies have failed to demonstrate an adverse effect of ionizing radiation. In the broadest study (14), which compared malignancy mortality rates in the 50 U.S. states against natural background levels of 0.100 - 0.250 rem/y, fifty-six malignancy types were tested for significance with simultaneous regressions against over 40 other geographical, economic, educational, ethnic, and pollution parameters. No increase in malignant mortality was found with increasing dose, but rather the reverse; a consistent and continuous decrease. Similar results were found for congenital malformations. These absences of detectable effects, combined with the dose-effect relationship at high doses, indicate that any increased incidence of cancer following low doses would have to be quite small and does not constitute an environmental hazard of significance. It has been estimated that to detect a statistically significant increase in the incidence of cancer at low doses would require that a population of 100,000 to 1,000,000 be exposed to doses of about 5 rem(44). Such a dose level is more than a thousand times higher than the calculated annual dose received by a member of the public living continuously on the boundary of the Pickering Generating Station.

In the past several years, allegations by E.J. Sternglass (15,16,17,18) of increased infant mortality in the vicinity of nuclear power stations have received considerable publicity. These have been intensively investigated by many qualified groups in the United States and world-wide (19,20,21,22,23,24,25,26), and none of their studies

have ever supported Sternglass' findings. Those refuting his work include the 15 past presidents of the Health Physics Society, the Unites States Public Health Service, the U.S. Environmental Protection Agency, the health departments in the states of New York, Pennsylvania, Michigan, and Illinois, the American Public Health Association, the American Academy of Pediatrics, and various other scientists at Oxford University, Dalhousie University, Halifax, St. Bartholomew's Hospital, London, and New York University. In a definitive evaluation of the biological effects of ionizing radiation (BEIR Report)(27), the U.S. National Academy of Sciences - National Research Council states,

> "It is clear that the correlations presented in support of the hypothesis depend on arbitrary selection of data supporting the hypothesis and the ignoring of those that do not. In several regards, the data used by Sternglass appear to be in error."
>
> "In short, there is at the present time no convincing evidence that the low levels of radiation in question are associated with increased risk of mortality in infancy."

Predictions of large numbers of deaths due to nuclear power put forward by Drs. J.W. Gofman and A.R. Tamplin have also been widely publicized. There are two shortcomings in their argument:

1. They assume that every person in the United States is exposed at the maximum U.S. dose limit of 0.170 rem/y for members of the general population. This is physically impossible due to dispersion phenomena if the maximum dose limit of 0.5 rem/y, for the public on the station boundary is complied with. Further, the design and operating dose targets, and actual operating experience, are about one hundred times lower than the boundary dose limit of 0.5 rem/y.

2. The U.S. Academy of Sciences, on reviewing Gofman and Tamplin's risk estimates, found they had overestimated the incidence of delayed somatic effects by ten to thirty times (27).

Based on the studies of exposed human populations outlined above, and using conservative assumptions, what is likely to be upper bound estimates of

potential somatic risks resulting from exposure to ionizing radiation have been made by international (28,29) and American authorities (27). These have recently been summarized by a committee of the National Research Council of Canada (6). The additional cancer deaths of all kinds, as a result of exposing one million persons to a single dose of 1 rem, are estimated at a maximum of about 100, or approximately 0.0001 per rem. It is emphasized that due to the imcompleteness of our knowledge, particularly at low doses and dose-rates, considerable caution must be exercised in applying such numerical risk estimates. Because of these uncertainties and in order to reduce the probability of underestimating the risk, such risk estimates are all based on a linear extrapolation from the incidence of effects at high doses down to zero dose, i.e. it is assumed that there is no threshold or safe dose at which no effects occur.

Nonetheless, substantial data exists, e.g. the Nagasaki leukemia cases (30) to suggest that the real dose response may be sigmoidal, giving fewer cases at low dose levels than the linear assumption would predict. Hence, the risk estimates are believed to be maximum estimates, with the actual risk lying between 0.0001 per rem and zero. As outlined by the United Nations Scientific Committee on the Effects of Atomic Radiation (31),

> "it is unlikely that the risk per unit dose at very low levels will be any greater than at high doses and is likely to be much less".

(c) Genetic Effects

Genetic effects, whether caused by ionizing radiation or other agents, result from changes in the male and female reproductive cells. The genetic effects <u>may</u> be expressed as increased frequencies of malformations or disease, reductions in fertility or increases in the likelihood of stillbirths. In the past few years there has been a great increase in knowledge concerning genetic effects of radiation at the cellular level, particularly on animal chromosomes (32). Used in conjunction with our knowledge of the occurrence of spontaneous genetic damage in humans, it enables estimates to be made of the genetic effects of radiation in human populations. It is not too difficult to estimate the increase in mutation rate caused by various levels of

radiation. The problem is that we have little basis for quantifying the increase in human disease resulting from the increased mutation rate. Any increase in mutation rate is conservatively viewed as harmful, but the social effect of even doubling the mutation rate may be very small in terms of additional human ill health. Obtaining such human information is very difficult for three reasons:

1) a relatively high incidence of normal genetic defects;

2) a lack of understanding and control over all other agents producing similar genetic mutations;

3) as a consequence of 1) and 2), the requirement for extremely large irradiated populations in order to make any small increase in the mutation rate statistically apparent.

Current risk estimates are dependent on a survey carried out in Northern Ireland about 16 years ago on the genetic incidence of normal defects (45). This suggested that about 6 people out of every 100 born alive will have more or less serious trouble at some time in their lives due to conditions largely or in part hereditary in origin. Genetically-determined disease seriously handicaps about half of these people, i.e. 3% of all live births. Animal experiments suggest that only one-third of these defects (1% of all live births) result from exposure to the natural radiation background to which we are all subjected (33), and that the bulk of the 1% consists of dominant traits. However, more recent data based on a study population of two million in British Columbia (34), suggests that the defect contribution from natural background radiation is less than 0.1% of liveborn. If this is confirmed, a doubling of the mutation rate due to ionizing radiation would be expected to raise the amount of genetic disease by one-tenth of a case per hundred liveborn (33), which is about 30 times lower than the existing official estimates (27),(28).

The principal human population studied in detail for genetic effects resulting from exposure to ionizing radiation is the children conceived after the explosions at Hiroshima and Nagasaki (35),(36). No significant differences have been observed in 30,000 children born to irradiated parents compared with 40,000 children of unexposed controls. None of the

measures of health and survival nor physical measurements, e.g. birth weight, abnormalities, sex ratio, development at 9 months and neonatal deaths, showed significant differences. It cannot, however, be concluded that genetic effects do not occur. It may be that the effect of these exposures, even given the relatively high dose and dose-rate levels, was not sufficient to produce observable effects above those which occur naturally in a population of this size. This lack of a detectable genetic effect in humans even at moderately high doses is, however, strikingly in contrast to the unequivocal evidence for somatic effects at that level.

One important conclusion from the animal genetic studies is that there is an effective, natural biological mechanism for repairing at least some radiation damage in reproductive cells (37)(38). This mechanism may also play an important part in reducing and perhaps preventing some of the previously discussed delayed diseases resulting from somatic effects in irradiated humans (39). In view of this more recent data on dose-rate effects, Russell concluded that the genetic hazard is about six times less than it was considered to be when the current risk estimates and dose standards were established.

Current genetic risk estimates by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)(28) and the United States Academy of Sciences BEIR Committee (27) are based on detailed study of the kinds of data outlined above. It is recognized that such estimates are subject to uncertainty, and they are put forward as reasonable guidelines, not as accurate scientific pronouncements. They are broadly based on the following positions:

a) 1% of liveborns have serious genetically-determined disease as a result of exposure to the natural radiation background;

b) for chronic irradiation, the dose that will double the natural mutation rate (doubling dose) is 20-200 rem, say 100 rem;

c) a linear relationship exists between dose and effect down to zero dose; and

d) 1/20th to 1/50th of the mutations may appear in the first generation following exposure.

The total genetic damage is estimated to be 300 cases per million persons exposed to a dose of 1 rem, or 3×10^{-4} genetic defects per man-rem. (If as outlined above the new data of Trimble (34) on the prevalence of dominant disease is accepted, the risk estimate is thirty times lower or 1×10^{-5} genetic defects per man-rem).

If a stable population of one million people were exposed to 0.001 rem/y for 30 years (the mean age of reproduction) as a result of the nuclear power program, the total additional cases of genetic disease would thus be about 10 against the natural background of 10,000 cases. As indicated previously, the current annual average dose-rate to individuals in the general population of Canada as a result of the nuclear power program is estimated at 0.000003 rem/y (6) or 300 times lower. Such risk estimates may help to put the assessment of potential adverse health effects of nuclear power into perspective, keeping in mind that these numbers could still substantially over-estimate the true risks.

(d) Maximum Permissible Doses

In Canada, the Atomic Energy Control Regulations specify Maximum Permismible Radiation Doses for both atomic energy workers and the public (4). In general, these limits are based on the recommendations of the International Commismion on Radiological Protection (ICRP)(41). The ICRP recommendations in turn rest upon the best available judgement of the somatic and genetic risks that such doses may entail. The considerations and biological data on which these recommendations are based have been broadly outlined above. Further details are extensively reviewed in the reports of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)(28) and the United States Academy of Sciences BEIR Committee(27).

The ICRP conservatively assumes that any exposure to ionizing radiation entails some risk of deleterious effects. However, unless man wishes to dispense with the potential benefits that accrue from activities involving exposure to ionizing radiation, he must recognize that there is some degree of risk which is acceptable to the individual and to society. Although the relationship between dose and risk is not currently known with precision, and it is often difficult to make quantitative evaluations of

benefits, the ICRP recommends Maximum Permissible Doses that will limit both somatic effects in individuals and hereditary effects in the population as a whole. As outlined above, 75 years of experience in the use of X-rays, radium and other radioactive materials, and radiation injury data on man and other organisms indicates that such maximum permissible doses are accompanied by a low probability of radiation injury.

As the general public includes children and does not, unlike atomic energy workers, make the choice of being exposed, and is not subject to the selection and medical surveillance required for atomic energy workers, it is undesirable to expose its individual members to the maximum permissible doses considered acceptable for radiation workers. The ICRP recommends and the Atomic Energy Control Regulations require, accordingly, that the dose limits for members of the public be a factor of ten below those for radiation workers.

In addition to these limits for individual members of the public, the AECB limits the total annual population dose in the vicinity of a nuclear power station. Both sets of limits are summarized in Table 2.3.2.2-1.

Despite the fact that even at the Maximum Permissible Doses for occupational workers, the risk of somatic and genetic effects are small, being expected to produce effects that could only be detectable by statistical methods applied to very large groups, the above dose limits are not regarded as design targets. Ontario Hydro follows the ICRP recommendation that all exposures should be maintained as low as is reasonably achievable(42). Ontario Hydro's design and operating target corresponds to a maximum dose to members of the public 100 times lower than the dose limits. The average performance at the large, multi-unit Pickering station is substantially better than this stringent design and operating target (Section 2.3.2.1).

Table 2.3.2.2-1

RADIATION DOSE LIMITS
FOR INDIVIDUAL MEMBERS OF THE PUBLIC

Organ	Annual Dose Limits
Whole Body, Gonads, Red Bone Marrow	0.5 rem
Skin, Bone, Thyroid	3 rem (1.5 rem to thyroid of children up to 16 years)
Other Single Organs	1.5 rem
Extremities	7.5 rem

POPULATION DOSE LIMITS

10^4 man-rem per year whole-body exposure

10^4 man-rem per year thyroid exposure

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Number

2.3.3 Non-Radioactive Aspects of Nuclear, Fossil and Heavy Water Plants

2.3.3.1 Air

(a) Regulations, Guidelines and Criteria

Provincial

The Ministry of the Environment, under the Environmental Protection Act, 1971, is the main body responsible for controlling air pollution in Ontario and administers and enforces regulations made under the Act. The Act defines air pollution:

"air pollution means the presence in the outdoor atmosphere of any air contaminant or contaminants in quantities that may cause discomfort to or endanger the health or safety of persons, or that may cause injury or damage to property or to plant or animal life or that may interfere with visibility or the normal conduct of transport or business;"

The operation of a power generating station must meet legal requirements regarding air pollution. These requirements may include any or all of the following regulations made under the Act, and its amendments:

(i) Limitations of sulphur content in fuel.

(ii) Criteria for desirable ambient air quality.

(iii) Standards for concentrations of air contaminants at a point of impingement.

(iv) Regulations on opacity of visible emissions.

(v) Limitations on generating station operation due to air pollution index regulations.

(vi) Regulations to prevent emissions of any air contaminant from causing discomfort to persons, loss of enjoyment of normal use of property, interference with normal conduct of business, or damage to property.

(vii) Requirements for dust separating equipment when burning solid fuel in suspension.

(viii) Regulations to prevent emissions of air contaminants from various construction operations.

At the present time, regulations limiting the sulphur content of fuels have only been applied to the Municipality of Metropolitan Toronto. The maximum sulphur content of fuel, effective January 1, 1973, is 1.5% for fuel oil grade number 6 and bituminous coal.

Desirable levels of certain contaminants have been set out in the legislation as "Ambient Air Quality Criteria".

The method for calculating the half-hour average concentration specifies the Pasquill-Gifford equation for dispersion and the Holland equation to determine the plume rise. Half-hour average concentrations are calculated for both C and D stability classes. The maximum value obtained must be within the point of impingement standard.

The regulations specify the allowable opacity of a visible emission expressed as its colour in shades of grey to black or the degree to which it obstructs the passage of light at the point of emission. For a period of not more than four minutes in any thirty-minute period, a visible emission from a source of combustion employing solid fuel may (a) be in shades of grey darker than No. 1, but not darker than No. 2 on the "Visible Emission Chart of the Province of Ontario", or (b) obstruct the passage of light to a degree greater than 20 per cent but no greater than 40 per cent.

An "Air Pollution Index" has been established by the Ontario Government and is used to give warning of, and to prevent, the adverse effects of a build-up of air pollution which may occur during prolonged periods of poor atmospheric dispersion conditions. Legislation provides for: (1) Air Advisory Level at API = 32 where sources of air pollution are to make preparation for the curtailment of their operation and (2) First Air Pollution Alert at API = 50 where sources of air pollution may be required to curtail operations. Both of these are dependent on meteorological forecasts of six hours of atmospheric conditions conducive to sustained or increased air pollution levels.

Contaminants emitted into the air from construction, alteration, demolition, drilling, blasting, crushing, screening or sandblasting must be controlled so that they are not carried beyond the limits of the property on which the operations are carried out.

Open fires and incinerators are also regulated by the Ministry of the Environment. Both require permits and must be operated in an approved manner with any control equipment deemed necessary by the Ministry.

In specific instances, Ontario Hydro has been required to conform to Ministerial Orders regarding atmospheric emissions from existing generating stations. The Program Approval or Control Orders have required changes in plant operating conditions and/or fuel specifications to reduce emissions.

In addition to adhering to these legal requirements, specified in the regulations, Ontario Hydro design new generating stations in consideration of existing and projected land use in the area, based on consultation with the Ministry of the Environment. Under these "Design Guidelines", maximum resulting ground level concentrations of pollutants under normal operating and atmospheric stability conditions must be maintained at an agreed level which is below the point of impingement standard.

For example, although the point of impingement standard for sulphur dioxide is 0.30 ppm (1/2 hr), the "Design Guidelines" for ground level concentrations are more restrictive as indicated in the table below.

Land Use Class	Concentration ppm
Undeveloped Region	0.20
Light Industrial Region	0.15
Heavy Industrial Region or Other Specific Concern	0.06

Emission rates of contaminants from power generating stations are not subject to regulation.

Federal

The Federal Department of the Environment is responsible for enforcing regulations under The Clean Air Act, 1971, relating to ambient air quality and control of air pollution in Canada. The Act, limited

in scope by the British North America Act, is designed to assist provincial agencies in maintaining safe ambient air quality levels and specifies three ranges of quality; tolerable, acceptable and desirable. National air quality objectives have been issued for the latter two levels for five major air pollutants; sulphur dioxide, particulate matter, carbon monoxide and total oxidants (ozone) and nitrogen oxides.

The maximum desirable level defines the long term goal for air quality, and provides a basis for a non-degradation policy for unpolluted parts of the country and for the continuing development of control technology.

The maximum acceptable level is intended to provide adequate protection against effects on soil, water, vegetation, materials, materials, animals, visibility, personal comfort and well-being.

The maximum tolerable levels, which are to be announced at a later date, are intended to indicate the onset of an "imminent danger" requiring immediate abatement action. Air pollution episodes would fall within this category.

The federal government is in the process of determining emission guidelines for thermal power generating stations. These will have material application as a minimum baseline standard.

International

The Canadian and United States federal governments, under the International Joint Commission, confer on transboundary emissions. This commission has no power of enforcement, but makes recommendations where international boundary problems exist. There are no proposed criteria which presently apply to generating stations in Ontario. There has been a recent formal agreement between the governments of Canada and the United States to give the IJC proposals force of law.

(b) Atmospheric Dispersion

Meteorology

Local meteorological conditions determine station design parameters, operating conditions, and stack design required to diffuse and disperse atmospheric emissions.

Data required to predict the dispersion of station atmospheric emissions include wind, temperature, atmospheric stability, vertical temperature profiles, inversions, lake breeze effect and mixing heights.

The dispersion of stack emissions is strongly influenced by local wind characteristics. The wind direction determines the area to which the plume will be dispersed, while the velocity determines the total area over which the plume will be dispersed. Wind velocity influences the eventual height to which the plume will rise and also the rate of dilution in the atmosphere. As the wind velocity increases, the plume rise decreases, hence the area over which the plume is dispersed decreases. However, the dilution rate of the plume increases with wind velocity. Therefore a critical wind velocity exists where the plume rise and dilution rate results in a maximum ground level concentration at a particular point.

Atmospheric stability generally defines the potential of the atmosphere to disperse airborne emissions and is determined by thermal stratification and wind shear. Temperature structure in the vertical is generally used as an indicator of the condition (1).

The change in temperature with height is referred to as the temperature lapse rate or environmental lapse rate. The reference term for temperature change with height is the dry adiabatic lapse rate. This refers to the cooling of a parcel of air at the rate of minus 1C per 100 meters as it is forced upward, expands due to lower pressure and hence cools. Turbulence tends to restrict the occurrence of this theoretical value, hence its most important function is as a reference term.

Topography

A plume over a city will be dispersed in an erratic manner due to turbulence created by the "heat island" effect of a city and the roughness due to the buildings. The buildings may also distort the shapes of plumes discharged over them or produce downwash on leeward walls.

A lakeshore site will be characterized by the lake breeze phenomena. The lake breeze contributes significantly to high occurrences of off-lake winds at lakeshore locations. In work at Douglas Point on Lake Huron it was found that off-lake winds occurred

70% and 80% of the time during the daytime hours in the spring and summer respectively. Lake breezes are actuated by the temperature difference between the air over land and water, and cause a movement of local air masses from off the lake. The lake breeze effect is generally not affected by normal strength local geostrophic winds but the intensity can sometimes be modified by pressure gradients. In the lake breeze, air from the lake passes over the land, rises and returns over the lake. Interpretation of this phenomena suggests that on certain days a probable continuous recirculation of an air mass from the lake over the land and back could occur. However, in an extensive 12 months study at the Wesleyville site no occurrence of this recirculation phenomenon was recorded. The lake breeze effect has been found to exist at least 15 km inland and 10 km offshore (2).

Plume Modelling

Mathematical models are used in the conceptual and engineering design phases to predict concentrations of emitted pollutants at various points in time and space after discharge. The models in use today include both theoretical and empirical approaches. Turner's work (3) in the U.S. Department of Health Education and Welfare Workbook of Atmospheric Dispersion estimates, provides an excellent reference for dispersion calculations. It can be supplemented by numerous publications on plume rise, particularly Briggs' "Plume Rise" or various Tennessee Valley Authority publications. Present philosophy of predictions of pollutant concentrations after discharge incorporates two distinct calculations. The first derives plume rise while the second calculates the dispersion of the plume in the atmosphere from the height derived from the plume rise calculation.

The main equation in use to determine the dispersion of pollutants is that of Pasquill (1). It assumes the profile of a plume emitted from a continuous source with effective emission height H will have a Gaussian distribution in both horizontal and vertical directions. The concentration is then determined from the formula:

$$\chi(x,y,z,h) = \frac{Q}{2\pi\sigma_y\sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\left\{\exp\left[-\frac{1}{2}\left(\frac{z-h}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+h}{\sigma_z}\right)^2\right]\right\}$$

where X is the concentration of gas or aerosols at x, y, and z distances from a continuous source

x, y and z are points in the three axes of the plume

sigma y and sigma z are the standard deviations of plume concentrations in the horizontal and vertical respectively

u is the mean wind speed affecting the plume

Q is the uniform emission rate of pollutant

h is the effective stack height (sum of the physical stack height and the plume rise)

The above discussion has related primarily to the "Coning" model, and related dispersion calculations where the environmental temperature lapse rate is assumed constant with height. Two further models are used to determine concentrations when the environmental lapse rate changes with height. The "limited mixing" model (plume trapping model) occurs when a stable layer exists above the plume and limits upward dispersion of the plume, therefore producing higher surface concentrations of plumes. TVA has found ground level concentrations to be three times those experience under normal coning conditions.

The "Inversion Breakup" model occurs when a plume is initially dispersed into a ground based stable layer. Solar radiation and subsequent mixing conditions produce an unstable layer (good mixing conditions) which forms at the surface and progresses upwards causing the plume to be dispersed to the ground. The resulting ground level concentrations are greater than those experienced under coning conditions and in the same range as the limited mixing model. This condition is usually associated with the breakup of nocturnal inversions, and therefore its duration is usually short (i.e., in the order of thirty to forty-five minutes). However, in the case of lakeshore types this condition could be for a much longer period in the order of two to five hours during the occurrence of a lake breeze. During this condition, a stable layer of air off the lake would be warmed from the surface due to solar radiation as this layer passes over the land. This warming of the lower layers would progress upwards from the ground as the plume continues inland, and would cause a fumigation condition when the unstable layer penetrates the plume.

TVA in a recent paper (4,5) has proposed formulas and graphs based on their experience for plume rise and dispersion calculations to determine ground level concentrations under these conditions. Djurfors (6) has also proposed formulas and graphical solutions for these calculations.

A further approach to determine ground level concentrations uses a statistics approach. Based on long term data, the probability of occurrence of certain concentrations could be predicted. In actual fact, a dilution factor is derived. However, it is postulated that this dilution factor, derived from numerous sources throughout the world, is applicable to all sites. For a long term averages this is probably correct, however, this approach will not enable us to predict short term occurrences due to local meteorological or topographical features. Unless data are available for a specific site to determine statistically the probability of occurrence of certain concentrations, we are not able to make these predictions.

The best recent summary on plume rise studies was by Briggs (7) in 1969. He summarized data from sixteen different sources and found the 2/3 power law to produce the best agreement. Briggs modified the findings by assuming h_{max} occurs within 10 stack heights. When Briggs summarized his work in 1969 there were over 30 plume rise formulas and they were appearing at a rate of 2 per year. All required empirical determination of one or more constants, and some are totally empirical. The rises predicted by various formulas may vary by a factor of 10. Some of the more prominent plume rise formulas include the work by Briggs (7), Holland (8), Stone & Clarke (9), Lucas, Moore & Spurr (10), Carson & Moses (11), Concawe (12), and Csandy (13).

Briggs' work resulted in formulas which have received wide usage by government agencies and industry. Based on the 2/3 power law he suggested the formula

$$\Delta h = 1.6\, F^{1/3} u^{-1} x^{2/3} \qquad (x < 10\, h_s)$$
$$\Delta h = 1.6\, F^{1/3} u^{-1} (10\, h_s)^{2/3} \qquad (x > 10\, h_s)$$

as a good working approximation of plume rise in neutral and unstable conditions. His basic formula has been widely accepted by the industries and is receiving widespread use. This is a formula presently favoured by Ontario Hydro. TVA have

incorporated a stability parameter to Briggs' 2/3 power law based on surveys at their power plants and are obtaining better agreement of plume rise estimation with field observations. The studies at Wesleyville and Nanticoke will provide Ontario Hydro with similar, more specific data for various atmospheric conditions.

(c) Emissions and Effects

(i) Sources of Emissions

Power Plants

A fossil fuel is a mixture of organic compounds of carbon and hydrogen which, on combustion, releases heat with the formation of carbon dioxide and water vapour. However, fuels contain other substances such as sulphur and numerous trace elements which are also released in various forms during combustion. Products of combustion from fossil-fuelled generating stations are vented to the atmosphere by means of tall stacks.

Coal-Fired Units

Coals used for power generation are ranked according to fixed carbon and heating values ranging from anthracite to lignite. The combustion of coal in the furnace results in the formation of normal combustion products, carbon dioxide and water plus other gases and particulate matter. These include sulphur oxides, nitrogen oxides, carbon monoxide, ash and other elements in trace quantities.

Sources of particulate in stack emissions are incombustibles in the original fuel and carbon resulting from incomplete combustion. With pulverized coal firing, and depending on the type of boiler, approximately 80% of the ash in the coal becomes flyash, and the remaining 20% is collected as bottom ash. Modern electrostatic precipitators can remove more than 99% of the flyash from the flue gas of coal-fired boilers.

Some of the particulates emitted to the atmosphere are submicron in size and are considered to have dispersion characteristics similar to a gas.

Particulates in the size range emitted have high light scattering properties and although the

quantities emitted are low they may be readily visible in the plume.

Emissions of sulphur oxides are mainly dependent on the sulphur content of the coal. During combustion, sulphur contained in the coal is oxidized to sulphur dioxide. Some sulphur trioxide is also produced, although in much smaller amounts. Approximately 95% of the sulphur contained in the bituminous coal is discharged to the atmosphere as sulphur dioxide; the remainder is accounted for as pyrites removed during pulverization or as sulphur trioxide emitted or adsorbed on particulates, or is never released by the ash.

It is predicted that the portion of sulphur converted to sulphur dioxide for lignite-fired units is considerably less than that for bituminous coal. The high alkaline content of the lignite fuel is responsible for retaining a greater portion of the sulphur in the fuel in the bottom ash and flyash (14).

Sulphur dioxide concentrations are typically in the range of 1500 to 2000 parts per million in the flue gases of Ontario Hydro's bituminous coal-fired boilers.

Nitric oxide is formed by the reaction of nitrogen with oxygen under high temperatures. The amount produced depends on the temperature and time history of the combustion products. Most of the nitrogen is made available by the combustion air. Nitrogen oxides emitted from a power generating station stack are mainly nitric oxide with small amounts of nitrogen dioxide. The concentration of nitric oxide in the flue gas of Ontario Hydro's bituminous coal-fired boilers is typically 500 to 600 parts per million.

Studies on coal burning stations, indicate most of the trace elements are retained in the ash after combustion and therefore removed by electrostatic precipitators.

Oil-Fired Units

Oil as fuel can be burned directly as crude oil or more usually as residual oil left after distilling off the more valuable light hydrocarbons. The ash content and the constituents of the ash depend greatly on the source of the crude oil. As crude oil

is distilled, ash is concentrated in the residual oil. The range of ash content is between 0 and 0.5% depending on the source of the crude. Residual oils containing high amounts of sulphur and ash may be blended with other oils to provide a better overall fuel. Although emissions from oil-fired stations are dependent on fuel constituents, they are, in general, similar to those emitted from coal-fired stations.

Particulate emissions from oil firing are the oil ash and unburned carbon. The unburned carbon loss may be reduced with higher excess air usage or with fuel oil additives. Although the ash content of oil is low and resulting emission levels low, electrostatic precipitators are used by Ontario Hydro to reduce plume visibility. The size of the particulates emitted during oil combustion have high light scattering characteristics.

Sulphur dioxide is produced in the burning of the sulphur in the fuel and a small part of this is oxidized to sulphur trioxide by atomic oxygen in the flame zone and in the superheater region where vanadium pentoxide deposits act as a catalyst for oxidation. In coal-fired units some of the sulphur trioxide formed is adsorbed on or reacts with the ash in the flue gas and is removed, but with the small amount of ash in fuel oils the sulphur trioxide remains in the gas stream. The high hydrogen content of the fuel oil produces a high moisture content in the combustion flue gases which combines with the sulphur trioxide to form sulphuric acid mist. For this reason, oil fired units are operated with higher flue gas exit temperatures to avoid the formation of corrosive acids.

Nitrogen oxide emissions depend on the type and intensity of fuel oil firing. Emissions may be reduced by two stage combustion and recirculation of flue gas to lower the peak flame temperature and thus lower nitric oxide production.

As discussed under coal-fired units, trace elements present in the fuel are released during combustion and are present in the flue gas. The fate of these elements is not well documented for oil, but it is expected that 90 to 95% of the particulate forms are removed by the electrostatic precipitators in a manner similar to that of coal-fired units. The gaseous forms would be emitted to the atmosphere. Elements released in small quantities after combustion include vanadium, mercury, nickel, selenium, fluorides and chlorides as well as uranium and thorium.

Gas-fired Units

Natural gas is primarily methane with some ethane and higher hydrocarbons along with inert gases in various amounts depending on the source.

Natural gas is a very clean fuel as both ash and sulphur oxides emissions are eliminated. The high flame temperatures associated with intense gas firing can produce high levels of nitrogen oxides. However, the production of nitric oxide can be greatly reduced by operating with low excess air, flue gas recirculation and two stage combustion.

Heavy Water Plants

Hydrogen sulphide is used in the production of deuterium oxide or heavy water and is normally recycled in the process. However small quantities of hydrogen sulphide are lost from the enriching process during purging of the enriching unit.

Modifications are in progress at Ontario Hydro's Bruce Heavy Water Plant which will enable some maintenance and operating releases of hydrogen sulphide to be recycled back into the process system. Many maintenance and operating releases have been eliminated and the overall losses of hydrogen sulphide from the plant have been reduced significantly during the fall and winter of 1973.

The primary purpose of constructing a flare stack is for the safe combustion of hydrogen sulphide and subsequent dispersion of the sulphur dioxide during an emergency situation. Hydrogen sulphide burns non-spontaneously in air to sulphur dioxide. The disposal, chemistry, environmental effects, toxicity and smell thresholds for sulphur dioxide are fairly well known. The industrial experience and general knowledge concerning hydrogen sulphide is less well documented. As a result of commissioning and experience with Bruce HWP A in 1973, Ontario Hydro has gained experience in the design, operating and maintenance measures necessary to ensure performance acceptable to regulatory authorities and to the surrounding communities.

(ii) Environmental Effects

The following discussion covers the effects of air pollution in general and the contribution to air pollution from electrical generating stations in

particular. In most cases of air pollution it is not possible to assign effects to a specific source of pollution or often to a specific type of pollutant. Emissions of pollutants from fossil-fuelled generating stations undoubtedly contribute to general air pollution and to any adverse effects of this pollution which may be measured.

Environmental effects of air pollutants cover a wide range of subjects including the effects on man, animals, plants, inanimate objects and climate.

Health Effects

Man has been concerned with air pollution and its effects on public health as far back as 1273, when the Clean Air Act was passed in England prohibiting the use of soft coal.

During the last decade, a vast number of reports have been published on the effects of air pollutants on human health. At the present time, studies on air pollution and its effects on human health are taking two major trends; toxicological laboratory studies performed under specific conditions, and epidemiological studies on populations.

Sufficient evidence from air pollution episodes is available to indicate that severe atmospheric pollution can affect health. It contributes to excesses of deaths, increased morbidity and the earlier onset of chronic respiratory diseases. There are, however, four main problems in summarizing conclusions from human studies reported in the literature. Firstly, the studies do not present a consensus that air pollutants at all levels affect public health. Secondly, the large number of environmental variables, usually not common to all studies, makes comparisons extremely difficult. Thirdly, some pollutants rarely occur alone and therefore precise pollutant effect relationships are difficult to determine. Fourthly, all the illnesses that can be caused by pollutants have much more obvious causes, such as lung cancer and cigarette smoking.

Toxicological studies show that high concentrations of sulphur dioxide affect the human respiratory system. However conclusions from epidemiological studies vary from some to no effect.

It is now generally held that particulates are a major cause of air pollution associated respiratory illness. However, in most of these cases, the particulate is thought to carry the damaging pollutant and may not necessarily be a specific cause.

Little work has been done on nitrogen dioxide in regard to human health. It does have some effect on sensitive groups and is generally thought to be more toxic than sulphur dioxide. The absence of convincing epidemiological studies makes it difficult to draw conclusions at the present time.

The trace elements commonly occurring in the flue gases from a fossil-fuelled generating station are generally conceded to be harmful to human life at much higher concentrations. Human studies, at the present time, do not give sufficient information for drawing firm conclusions on the effects of these pollutants on human health in the concentrations occurring in air polluted by generating station emissions.

Effects on Animals

Air pollutants can exert their effect on animals via different routes. They may be inhaled, absorbed through the skin, or deposited on vegetation or soil and later ingested. Published data generally relate to livestock effects, presumably because of easier detectability and greater economic significance. However, there is no reason to doubt that comparable wild and domesticated animals are equally susceptible. The effects of pollutants on animal life may often be similar to those in humans. Nearly all controlled studies have involved small laboratory animals, such as guinea pigs, mice, rats and rabbits, because of their relatively high sensitivity to respiratory irritation.

For herbivorous animals ingestion of contaminated vegetation is probably more important than inhalation, since estimates for animals grazing in a polluted zone show that the average daily intake of pollutants by ingestion is in the order of a hundred times larger than by inhalation (15). Inhalation of industrial pollutants by livestock has been of little apparent significance because concentrations that would be noticeably toxic to animals via inhalation or direct contact would often be more readily detected in humans. This relativity has been illustrated in epidemiological studies of major air pollution disasters.

Since toxic pollutant material may first be deposited on forage and later ingested, it is very difficult to relate air concentrations at a given time or place with subsequent effects. Hazardous concentrations could accumulate on vegetation even when ambient atmospheric levels are below those considered harmful. Geographical and meteorological conditions influence the amount deposited in a given area, while other factors determine the degree to which the deposited pollutant adheres to, or is absorbed by, vegetation.

Observations appear to suggest that animals, through various inherent protective mechanisms, are well adjusted to cope with normal ambient levels of air pollution without impairment of their health. However, some chronic effects may not yet have been detected.

Effects on Vegetation

Plants are considered to be the most sensitive organisms to air pollutants. The effects of air pollutants from industrial sources on vegetation have been studied for a number of years. Several excellent reviews of the effects of air pollution on vegetation have been published (15,16). Effects of air pollutants at concentrations exceeding injury thresholds are such that they disrupt cellular and metabolic integrity, which may include the destruction of cell membranes, especially plasma membranes (enclosing each cell) and chloroplasts (site of photosynthesis). Components of these membranes may be oxidized by pollutants such as ozone and peroxyacetylnitrate or reduced and pH altered by a pollutant such as sulphur dioxide. Loss of plasma membrane integrity results in plasmolysis and tissue collapse, and chloroplast destruction disrupts photosynthesis, the process by which plants capture energy and produce their food. Chlorosis (loss of chlorophyll) is often associated with necrosis (localized death of tissue). Growth alterations include reduction in growth, twisting and abnormal elongation patterns. In extreme cases, defoliation and death of the plant may result. Susceptibility to air pollutants varies from species to species and between varieties within the species. This is mainly a function of genetic variability, although nutrition and growth stages are also important. The overall effect of these pollutants on the plant community is dependent upon many factors, including concentration and type of toxicant, type of plant material exposed,

length of exposure, weather (temperature, relative humidity and light intensity), and other environmental conditions. In fact, the physiological well-being of a given plant may be the most important factor in air pollution injury. The study of the effects of pollutants on vegetation is important not only because of the obvious relationship of such effects to agricultural production, forest resources, conservation of sensitive species and maintenance of ecological balance, but also because many plants can serve as indicators of the presence of pollutants.

Effects on Climate

Emissions from fossil-fuelled stations which may affect the climate include particulates, carbon dioxide and water vapour. These effects are local but interaction of regional atmospheric shifts could in turn result in long-range climatic changes.

Particulates emitted in increasing amounts into the atmosphere, reflect incident sunlight away from the earth's surface and may be partly responsible for the cooling trend evidenced since around 1945 (17). Carbon dioxide and water vapour, both produced by fossil fuel combustion and not generally thought of as pollutants, may have an opposite effect. Both substances transmit incoming solar radiation but block the longer wave length reflected radiation. They thus intercept some of the outbound heat flow that would otherwise escape to space and redirect it back to the surface. This is called the "greenhouse effect". Water vapour can modify the temperature structure through the greenhouse effect but it can also affect climate by causing an increase in cloud formation. The concentration of water vapour in the atmosphere does not seem to have been much affected by man. The water vapour produced in burning fossil fuels stay relatively close to the surface of the earth, and, while it may have local effects, is a small factor compared to water vapour moving through the natural hydrological cycle. Carbon dioxide, by contrast, mixes throughout the atmosphere. Measurements show that its global concentration increased by 10 per cent between 1890 and 1970. Much of the increase apparently came from the combustion of fossil fuel. Future atmospheric carbon dioxide concentrations depend on the growth rate of fossil fuel combustion and on the distribution of total produced carbon dioxide among the atmosphere, oceans and the biosphere. Elaborate calculations indicate that continuing present trends in fossil fuel

consumption could lead to an increase of 0.8°C in the average surface temperature of the globe by the year 2000. The theory of carbon dioxide warming is clearly in direct conflict with the current trends in temperature; the biosphere seems to be cooling rather than warming up. The argument has often been put forth that an increase in the particulate content of the troposphere could counteract the effect of carbon dioxide and water vapour to produce a downward spiral of temperatures. Recently, however, a number of workers have criticized the neglect of aerosol absorption, which would tend to warm the biosphere.

Aerosols, however, also act as freezing and cloud condensation nuclei to initiate precipitation and modify cloud structure. Accumulation of anthropogenic nuclei at the proper concentrations could well increase and modify cloud and cause a decreasing surface temperature. The effect of aerosols on cloud modification may well be a significant factor in explaining the decreasing temperature of the planet. It is evident that many questions concerning the possible long term climate effects remain unanswered. Present theories appear contradictory and more research is needed to resolve these conflicts.

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Line Number

2.3.3.2 Water

(a) Regulations, Guidelines and Criteria

The main body of provincial legislation for controlling discharges to water and the resulting water quality and biological effects is contained in the Ontario Water Resources Act. This Act gives the Ministry of the Environment the authority to supervise all surface and ground waters in Ontario. With respect to discharges, Section 30 states:

"Under sections 31, 32, 34 and 36, the quality of water shall be deemed impaired if, notwithstanding that the quality of the water is not or may not become impaired, the material deposited or discharged or any derivative of such material causes or may cause injury to any person, animal, bird or other living thing as a result of the use or consumption of any plant, fish or other living matter or thing in the water or in the soil in contact with the water."

The Ministry of the Environment outlines its criteria in the publication "Guidelines and Criteria for Water Quality Management in Ontario". These guidelines and criteria do not have force of law, but there are legal procedures under the Act for enforcing compliance. For generating stations located on the shores of the Great Lakes there are additional guidelines for control of heated discharges. In adhering to these objectives, Ontario Hydro will consult with the Ministry of the Environment and submit applications for permits or approval for specific aspects of the proposed project which may have water quality implications. These may include:

(i) The maximum allowable temperature rise between cooling water intake and discharge as well as the maximum allowable discharge temperature.

(ii) The total volume of water to be used for condenser cooling and auxiliary services including domestic water supply.

(iii) A prediction of the area of the receiving water body which will be occupied by the thermal discharge under various climatological conditions at full load.

(iv) Discharge to the water with respect to possible biological changes or influences.

(v) Miscellaneous discharges, e.g., from the water treatment plant, ash and coal pile drainage, site and plant drainage, boiler blowdown, bottom ash dewatering effluent, oil discharges, and effluent from domestic sewage treatment.

(vi) Temporary effects on water quality during dredging and dumping operations.

(vii) Batch releases of chemicals.

General guidelines for the control of heated discharges to the Great Lakes were provided in the Task Group report to the Advisory Committee on Pollution Control in May 1971 (1). In 1972, these general guidelines were further developed by the Ministry of the Environment, working with Ontario Hydro (2), into policies and guidelines and environmental programs related to open circuit cooling using waters of the Great Lakes. The main points of these guidelines as they exist today are believed to be in general agreement with the intent of the Environmental Assessment Act and include:

(1) The site selection process for new thermal-electric generating stations involves a public participation procedure and the continuing step-by-step participation of the various concerned provincial and federal ministries.

(2) After site acquisition, a one-year environmental on-site program includes studies on the hydrological and biological aspects of the site. As a result of these studies, a once-through cooling system is proposed for the project which has to meet with the approval of the concerned ministries.

(3) Pre- and post-operational hydrological and biological studies on the once-through cooling system are carried out so that any impact on the lake environment can be measured against the original conditions.

(4) Limits on the temperature rise and maximum discharge temperatures are specified by the Ministry of the Environment for each station before approval is given. These limits are subject to review following post-operational experience.

(5) Ontario Hydro will be required to investigate alternative methods of discharging condenser cooling water to the Great Lakes, such as for example, offshore submerged diffuser outfalls (3,4). These studies will complement existing work being done by, and future studies to be required of Ontario Hydro with respect to means of cooling the discharges.

(6) Ontario Hydro will be required to conduct comprehensive lake studies for the purpose of obtaining information regarding biological, physical and chemical facts of once-through cooling (4).

(7) Pending the development of an adequate data base from the studies mentioned in the preceding sections, new sites proposed by Ontario Hydro will be examined for suitability on a case-by-case basis.

Contingency planning for inadvertent discharges or spills will be based on Ontario Hydro Management Guides (e.g. 5).

The Ministry of Natural Resources administers the Lakes and Rivers Improvement Act, the Conservation Authorities Act, the Beach Protection Act, and some provisions of the Federal Fisheries Act within the province. In practice, there is consultation between the Ministry of the Environment and the Ministry of Natural Resources, both of which have responsibilities for protection of the aquatic environment.

The objective of the Lakes and Rivers Improvement Act is to provide for the use of waters of the lakes and rivers of Ontario and to regulate improvements in them, and to provide for:

(i) The preservation and equitable exercise of public rights in or over such waters.

(ii) The protection of the interest of the riparian owners.

(iii) The use, management and perpetuation of the fish, wildlife and other natural resources dependent on these waters.

(iv) The preservation of the natural amenities of these waters and their shores and banks.

(v) Ensuring the suitability of the location and nature of improvements, including maintenance and operation.

Under this Act, any proposed construction, repair, improvement or removal of a dam in any lake or river (creeks and streams included), or "occupied water privilege" for hydraulic purposes involving construction, improvement or removal of dams, variation in lake water levels, diversion of streams, and other related effects, is subject to approval by the Ministry of Natural Resources.

The objective of any conservation authority is to undertake and establish, in the area over which it has jurisdiction, a program designed to promote the conservation, restoration, development and management of natural resources other than gas, oil, coal and minerals, subject to approval by the Ministry of Natural Resources. Under the Conservation Authorities Act, an authority may regulate, restrict or prohibit the following:

(a) The use of water in or from rivers, streams, inland lakes, ponds, swamps, and natural or artificially constructed depressions in rivers or streams.

(b) The diversion, straightening, or otherwise interfering with the existing channel of a river, creek, stream or watercourse.

(c) The construction of any building or structure in or on a pond or swamp or in any other area susceptible to flooding (below the high water mark).

(d) The placing or dumping of any fill in defined areas such that the control of flooding or pollution may be adversely affected.

Federal

The Federal Government may enact legislation on discharges to water by virtue of its responsibility for international and interprovincial waters and fisheries. The Canada Water Act, 1970, provides for the establishment and operation of federal - provincial water quality management areas. The Act prohibits the disposal of waste, including heat, into water in any given management area except in quantities under conditions prescribed by the

regulations. No regulations concerning thermal discharges have been made under The Act to date.

A 1970 amendment to the Fisheries Act, 1952, prohibits the deposition in waters of any wastes, including heat, which will degrade the water quality. Under this Act, Environment Canada may enquire into a company's plans for expansion and can demand modifications to its anti-pollution measures if considered necessary to protect the fisheries waters.

Disposal of dredgings in a lake falls under the provisions of the Navigable Waters Protection Act, 1970, which is enforced by the Federal Ministry of Transport. This Ministry now refers an application back to the Provincial Ministries of the Environment and Natural Resources to determine if the proposed dredging and dumping procedure will have any adverse environmental effect. These two Ministries provide an assessment or comments to the Ministry of Transport before a license to dredge and dump is issued.

International

The International Joint Commission (IJC) has proposed water quality objectives for Lakes Erie, Ontario, the International Section of the St. Lawrence River and the connecting channels of the Great Lakes.

(b) Circulating Cooling Water

Introduction

Ontario Hydro presently employs once-through cooling at all thermal generating stations, using the natural cooling resource provided by the Great Lakes as a sink from which the heat is transferred to the atmosphere. Once-through cooling is the most economic method of condensing steam so its use produces substantial savings to the province in the form of cheaper electricity. Ontario Hydro recognizes that as with all renewable natural resources, excessive use may lead to harm and loss of a resource. The main concern expressed by the regulatory agencies relates to the thermal modification of the near shore areas where fish spawning and migration may occur.

Hydrological and Biological Studies on Thermal Discharges

Environmental studies were started in the late 1960's, some in conjunction with the Ministries of the Environment and Natural Resources to provide data on the effects of the cooling systems and to meet the concerns of these ministries.

These studies have continued to date (6), and such data have been subsequently obtained in all at about ten different sites (7). In general, the hydrologic data were obtained to provide information for the design of the stations and to provide background and post-operational environmental information which would assist in enabling any effects on the environment to be assessed. After stations came into operation, special investigations were made to determine the size and nature of the thermal plume, and analysis of this information enabled a plume prediction model to be developed (8). Studies utilizing field and laboratory information are underway to develop a more general mathematical model for thermal plume prediction. More recently, thermal hydraulic models have been constructed and tested to study improvements in the intake arrangements and the thermal plume action.

In general, at each site where a station is proposed, measurements are made of: offshore water temperatures at a variety of locations and depths; water currents at several locations; wind speeds and directions for correlation with water currents; the extent and nature of ice formations; and the location of weed beds and their ultimate deposition on shore. Such measurements are made well before a station comes into operation and are continued after operation begins to enable any changes to be detected.

A very large amount of data has been obtained and processed and is given in annual reports for the various locations. Results from these programs are too numerous to give in detail, however certain results on water temperatures and currents are of interest.

At all open-lake sites on Lake Ontario and Lake Huron, and to a lesser degree on Lake Erie, it was found that during the summer period there were large, rapid, and frequent variations in water temperatures extending out to depths of 70 feet or more. It has been found that these temperatures are typical of most sites along the north shore of Lake Ontario. It

is of interest to note that during the summer months variations in temperature of up to 25°F can occur within very short time periods at all three depths where observations were made.

At all sites it was found that the water currents were predominately alongshore, and their direction and magnitude appeared to be largely dependent on direction, speed and duration of the winds.

After stations come into operation, special measurement programs are carried out to determine the physical shape, extent, and characteristics of the thermal plume. Temperature measurements are made on a grid encompassing the plume using a boat and equipment including water temperature measuring probes. Vertical temperature profiles are measured at selected points. Surveys have been made of the plumes at Lakeview, Pickering, Lambton and Thunder Bay and surveys at Nanticoke and Lennox are planned.

The most extensive plume investigation so far has been at the Lakeview station where, during the years 1969-71, a total of 53 temperature surveys were made under a variety of different climatic and operational conditions (8). As the thermal plume action is affected by many uncontrolled variables, e.g., wind, temperature, currents, etc., many measurements are required to cover an adequate range of conditions. In general, it was found that the thermal plumes floated on the cooler lake water and were between five and ten feet thick. While the path depended largely on the wind and ambient current, it was found that the plumes extended a maximum of about two miles where all measureable temperature effects disappear. The analysis indicated well defined relationships between temperature differences, plume area and shape, and the trajectory could be approximated by taking into account wind direction and outfall characteristics. A phenomenological model resulted which for a given season, temperature difference, and wind situation, produced plumes which generally agreed with the Lakeview data (8,9).

The prediction of thermal plumes at proposed stations is important in determining the optimum location for intake and outfall arrangements and in determining the area of possible environmental effect. The development of accurate predictive models is difficult because of the complex nature of the physical processes and the many variables involved. Ontario Hydro's approach has been to measure actual plumes from large stations in the Great Lakes

environment, and then develop predictive models which can be verified.

The phenomenological model has been utilized in plume predictions at proposed sites and appears to give reasonably good results. Work is underway in the development of a more general model that will utilize the results of plume measurements from other stations. Studies of buoyant surface jets under ambient cross flows have been made and the physical processes studied and results obtained will be incorporated in the model. It is expected that this model will provide a superior predictive ability for proposed stations including those dissimilar from Lakeview.

A large thermal hydraulic model has been constructed of the site of the Pickering Nuclear Station, reproducing some 2-1/2 miles of Lake Ontario shoreline and extending about 1-1/4 miles out into the lake. The model is equipped with heaters to simulate the thermal discharges of both the present station and the planned extension. The model scale is 1:120, and some 150 temperature sensors continuously monitor the water temperatures through the model. A computer is utilized to periodically scan these measurements and when stabilized, plot temperatures on a map of the model on which isotherms are drawn. The water supply to the model is arranged so that ambient lake currents can be reproduced. As extensive measurements have been made of the actual lake currents and of the thermal plumes from the existing station, a unique opportunity existed to verify the model to actual conditions and assure its proper simulation.

The purpose of the model was twofold. The first was to study existing intake arrangements with respect to problems of recirculation, entrainment of silt and weeds, and to develop remedial measures. The second purpose was to study the actions and interactions of the thermal plumes from the existing station and its extension to determine satisfactory intake and outfall arrangements. For such purposes a physical model is very advantageous as it can simulate the effect of topography and structures and the complex interaction between the thermal plumes and the ambient currents. Similar tests have been carried out in the Darlington GS A cooling water system.

The great majority of biological and water quality investigations by Ontario Hydro have been concerned with the effects of thermal discharges on the near-shore areas surrounding a generating station site (12,13,14). The earlier studies which started in 1968 were carried out at existing operating stations (10). In the same year, a major cooperative study, between the Ministries of the Environment and Natural Resources and Ontario Hydro (and joined later by Stelco and Texaco) was started at the Nanticoke coal burning station, which was designed to acquire data covering the period three years prior to commissioning through to the post-operational period, a total time of at least ten years (6). More recent studies are now carried out earlier in the life cycle of a generating station. Prior to the pre- and post-operational investigations, Ontario Hydro now carries out a year's on-site investigation during the site development phase, the results of which are included in the Environmental Assessment submitted to the Minister of Energy for approval of a project.

The general objective for most of the existing studies has been to determine or predict the influences of elevated temperature on certain trophic levels or segments of the near-shore aquatic community. Over the years, investigations have been carried out to attempt to resolve the numerous and changing concerns that have been expressed. Studies have increased in scope and complexity to detect and assess effects which are subtle and may have far-field implications. This evolution of objectives has made it progressively more challenging to develop appropriate site studies. An example of a major shift in emphasis has been from the direct thermal effects on aquatic biota to the effects of entrainment. As a result of extensive discussions on once-through cooling with members of the Ministry of the Environment and the Ministry of Natural Resources in 1972 and 1973, Ontario Hydro developed and obtained Board Approval in 1974 for a five-year program of investigations of "Improved" Once-Through Cooling Systems (11). The objective of these investigations of alternative designs of intake, screening and handling and cooling discharge arrangements is to develop systems which would minimize the intake of organisms, minimuze the physical and thermal impact on the intake and entrainment of organisms and on the aquatic life in the littoral zones and lake as a whole.

Some general results of on-site studies to date are summarized below.

Depletion of dissolved oxygen in the heated circulating cooling water was found, by measurement, not to occur.

Studies on the growth of the nuisance alga Cladophora have yielded varying results. At present, it is not clear if current or temperature is the dominant factor influencing increased growth. Yearly production appears to be similar in heated and unheated areas possibly because the optimum temperature for growth may be below maximum thermal discharge temperatures.

Benthic organisms generally increase in abundance at sampling locations close to the discharge. It is not known if this is due to a direct thermal influence or to increases in water flows and to increased food availability from entrained plankton. However, differences in diversity indices and numbers of taxa between stations are generally small or insignificant, and changes appear to go through similar seasonal yearly fluctuations. No major shifts or irreversible changes have been found to occur in species composition due to the thermal discharge.

Fish distribution off the site is modified by the thermal discharge. With some exceptions, each fish species tends to be attracted to the heated area up to its upper preferred temperature and then leave. Cold water species are more common in the discharge area in spring and fall but leave in the summer. Species may tend to vertically distribute themselves in accordance with their preferred temperature and the temperature gradient within the discharge. In winter, most species, including cold water species, leave the area for the deeper waters of the lake. Residency time in the heated discharge is only a few hours in three species that have been studied (15,16). Currents with no heat tend to attract river spawning species. No symptons of gas bubble disease have been detected in fish caught in the thermal discharge areas. No fish kills have been detected due to rapid temperature drop following station shutdown.

Phytoplankton populations are generally similar in discharge and controlled areas, though shifts from

diatom-dominated to green algae-dominated populations may occur in the warmer months of the year.

Results of site studies to date suggest that the littoral zones influenced by thermal discharges have species diversities and populations of organisms which are little different from control littoral zone areas. Far greater changes take place due to the seasons and the major temperature fluctuations typical of the majority of the Great Lakes shoreline.

(c) Chemical Releases

Introduction

Electrical generating stations discharge relatively small amounts of chemicals. As part of the project approval for new generating stations, Ontario Hydro provides details of proposed pollution control equipment, expected discharge concentrations of chemicals and in some cases the amounts. Permits and approvals are provided based on the levels of emissions required for the maintenance of acceptable water quality as laid down by the Ministry of the Environment in the Guidelines and Criteria for Water Quality Management.

Extensive data are being accumulated on the majority of chemicals being discharged based on toxicological, chemical and dispersions studies. In operating plants, Ontario Hydro is continuing to upgrade those systems which release some chemicals to the water body. The trend is to progressively reduce the levels of discharged chemicals and in some cases attempts are being made to completely eliminate them.

Chlorine

Addition of chlorine to the circulating cooling water entering the condenser is the standard method for maintaining the condenser tubes free of bacterial slime growths which, unless checked, constrict water flow through the condenser and affect the thermal efficiency of the station.

There are no specific regulations on the concentration of chlorine in cooling water discharges. However, guidelines have been proposed by the Ministry of the Environment, and approvals for new stations are conditional on achieving a given concentration of residual, chlorine in the effluent from each condenser. In practice, each condenser

half is chlorinated sequentially resulting in condenser effluent concentrations being further reduced by dilution and reaction with the unchlorinated streams from other operating units.

Current studies include the development of instrumentation sensitive enough to detect and measure the extremely low concentrations of residual chlorine in these effluents. It is planned to use such instrument for routinely monitoring concentrations entering the lake.

An alternative to chlorination which has been tested on one unit at Nanticoke GS is the use of a mechanical condenser tube cleaning system. In practice, the quality of water at most of Ontario Hydro's stations on the Great Lakes is such that chlorination is not routinely required. At new stations, only space and minimal piping provisions are being considered for possible future chlorination or for the mechanical cleaning method.

Hydrogen Sulphide

Extraction of deuterium in the form of deuterium oxide, or heavy water, is achieved at Ontario Hydro's Heavy Water Plants by a process involving the solution of hydrogen sulphide in water. Small amounts of hydrogen sulphide, not recovered for recycling, are discharged into the process water, which, after dilution with station cooling water is discharged to the lake.

The Ministry of the Environment has set hourly and daily limits on the amount of hydrogen sulphide which may be emitted in the water effluent. These levels are based on data obtained on the toxicity of hydrogen sulphide towards sensitive aquatic species.

Ontario Hydro is carrying out its own evaluations (17). Dispersion studies have shown that the depletion of hydrogen sulphide in the thermal effluent follows closely the decline in temperature. A further planned laboratory study is on the toxicity of hydrogen sulphide towards fish native to Lake Huron. Results of this proposed study will be used to define environmentally acceptable concentrations of hydrogen sulphide in the discharge.

Line Number

Miscellaneous Discharges

In keeping with The Objectives for Water Quality Control in the Province of Ontario and the overall policy of protecting water quality while recognizing essential use for waste water disposal, the Ministry of the Environment requires that Ontario Hydro, along with industry, discharging wastes into watercourses, to limit, destroy, remove or modify any waste constituents that may be in question. This may apply to waste constituents that are not readily removed by conventional treatment and are only reduced by dilution and other natural stream purification processes.

These wastes include:

- Oily water
- Boiler water treatment plant effluents
- Ash sluicing effluent
- Boiler and wash effluent
- Coal pile drainage
- Ash disposal area drainage
- Air preheater wash effluent
- Sewage lagoon effluent

2.3.3.3 Land

The sources and quantities of solid wastes from both fossil-fuelled and nuclear fuelled stations have been identified in some detail in the environmental assessment for each project. Descriptions of the various sources and quantities of wastes with the proposed methods of disposal are reviewed with the appropriate regulatory agencies prior to approval of a new generating station. At this stage, there has to be approval in principal for the disposal methods. Subsequently, approval has to be obtained from the Ministry of the Environment for the collection, transportation and disposal of individual types of wastes during construction and operation of a generating station.

The most important solid waste from an operating fossil-fuelled generating station are fly and bottom ash. Wastes common to both fossil-fuelled and nuclear-fuelled generating stations include screenhouse materials consisting mostly of floating debris, fish and weeds; water treatment plant sludge; and sewage sludge and oil at construction sites. Other important wastes are from construction materials and from the construction camp, if present. Ontario Hydro disposes of solid wastes in accordance

with the procedures set down by the Regulatory Agencies.

Fly ash, the solid waste produced in greatest volume from coal-burning stations, is presently being satisfactorily disposed of in land fill sites. Some fly ash is being used in light weight aggregate.

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2.3.4 Hydraulic Development

The environmental effects of a hydraulic project depend largely on its location and size. Such effects are not necessarily adverse and in some cases the projects may be designed to produce some environmental benefits such as provision of an area for water-based recreational activities.

Changes in water quality may occur both upstream and downstream of a project. In the flooded areas there is generally a deterioration in water quality during the early years of operation. Long term water quality changes are associated with the degree of initial clearing of vegetation, the type of operation of the storage facilities and such factors as the stability of the reservoir shorelines. Downstream of the facility, the water may have a lower silt load and the fluctuating flow will influence water levels and erosion and deposition patterns. Temperatures downstream will be influenced by the mode of operation of the facility. Influences on the aquatic environment are usually site specific and are associated with the changes in water temperatures, nutrient levels and water levels and flows. Generally, populations and species distribution of native fish species are found to change both upstream and downstream of the facility. Little success has been recorded in transporting fish over hydroelectric dams and through storage reservoirs. Terrestrial fauna are adversely influenced by loss of habitat due to reservoir flooding, road construction and transmission line right-of-way construction.

Ontario's remaining undeveloped hydraulic resources are located in relatively remote areas of the Province. Apart from the immediate effects on land utilization such as headpond flooding, roads, airports and other forms of communication, long term impacts on the region may arise due to its increased accessibility.

Ontario Hydro's hydraulic generating stations were constructed before the need was perceived for a detailed environmental analysis. New hydraulic generating stations will require a thorough environmental investigation as now required under the provisions of the Environmental Assessment Act.

In an aboveground pumped storage facility where water is taken from an existing water body to a reservoir at a higher level, the main terrestrial influences

will be in the loss of land and natural habitat. Entrained aquatic organisms, particularly fish, will generally experience heavy mortality due to mechanical damage during pumping and to changes in pressure. In the upper reservoir, any large changes in water levels would tend to provide an unfavourable environment for maintenance of a stable aquatic community, particularly if erosion of the reservoir banks was not controlled. Changes in water level would discourage development of water orientated recreational activities.

Where water is pumped from an underground storage reservoir to an upper water body, the main impact would be during the construction phase where large volumes of rock must be removed from the site. During operation, entrained organisms would be killed by mechanical and pressure stresses. This concern would also present a possible water quality problem if large quantities of organisms are entrained. If the upper reservoir was a discrete water body, dedicated to pumped storage, these entrainment concerns would not exist. Some heat will be added to the pumped water by friction and by contact with subterranean rock. The overall impact of pump storage facilities could, therefore, vary from low to high depending on the type of reservoirs used.